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Environmental management requirements and practices in river-based artisanal and small-scale sand mining: a case study from the Progo River, Indonesia

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Abstract

Sand is extracted in greater volumes than any other mineral resource, with global consumption reaching approximately 50 billion tonnes annually. In Indonesia, artisanal and small-scale sand mining (ASSM) accounts for 94% of national sand production. However, the implementation of environmental management requirements by formally permitted operations remains poorly understood. This study investigates environmental management and post-mining land rehabilitation in a formally permitted ASSM operation on the Progo River in Yogyakarta Special Province, Indonesia. Drawing on content analysis of the operation's environmental management and monitoring document, semi-structured interviews with 4 miners from the same mining group and 3 environmental consultants, and direct field observations, the study compares documented obligations with onsite practices across all operational stages. Three patterns emerge. First, the environmental management and monitoring document primarily serves as a permit requirement rather than an operational guide: once the permit is issued, miners rarely consult it and operational decisions revert to miners' own experiences and judgment. Second, several requirements are too generic; drawn from broader mining contexts rather than designed for the specific conditions of river-based sand extraction, they lead to predictable gaps between formal requirements and operational realities. Third, post-mining governance is the weakest stage: a site visit 5 months after expiration of the permit found that none of the formal closure requirements had been fulfilled. Despite these gaps, miners demonstrated practical environmental management, including onsite oil containment, topsoil storage and return, and conversion of ex-mining areas into productive fishponds and farmland. These community-driven practices are not captured in the regulatory document. This study concludes that improving governance in river-based ASSM requires technical guidance tailored to on-the-ground conditions, monitoring approaches suited to a dynamic river environment, and stronger post-mining obligations with defined outcomes and timelines.

Keywords: *artisanal and small-scale sand mining, environmental governance, environmental compliance, river mining, post-mining rehabilitation*

1 Introduction

Sand is essential for human development and supports multiple sectors, particularly construction and infrastructure. As the second-most-consumed resource globally (United Nations Environment Programme [UNEP] 2019), demand for sand continues to accelerate, particularly across the Global South. However, increasing extraction has led to significant environmental and social challenges, prompting UNEP (2019) to classify this as a 'major sustainability challenge of the 21st century'.

Not all sand is suitable for construction or industrial applications. Its suitability depends on the sand's physical properties, particularly its size and shape. River sand is characterised by favourable physical properties,

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including well-graded particle size distribution, appropriate bulk density and cleanliness, making it suitable for concrete production and other construction applications (Gavriletea 2017). Consequently, river sand has become a primary source for construction materials, especially in developing countries (Abu & Peprah 2020). However, unsustainable sand extraction in rivers could result in significant environmental and social impacts. Poorly managed sand mining disrupts soil stability and river morphology, leading to erosion, landslides and riverbank collapse (Arjun et al. 2023). Beyond environmental damage, these impacts threaten infrastructure, potentially displacing communities and disrupting farming activity (Loc et al. 2021).

These concerns are particularly relevant in Indonesia, where sand production is dominated by artisanal and small-scale sand mining (ASSM). In 2022 ASSM accounted for 94% of national sand production; approximately 59.66 million m^3(BPS – Statistics Indonesia, 2023; BPS Provinsi Kalimantan Timur/Statistics Kalimantan Timur Province 2024). Despite this scale, how environmental management requirements function in this sector remains poorly understood. In Indonesia, small-scale mining operations are regulated under the Pertambangan Rakyat (People's Mining) category, with permits issued as Izin Pertambangan Rakyat (IPR – People's Mining Permit). In this study, ASSM refers specifically to formally permitted IPR operations extracting sand from rivers.

Literature on sand mining predominantly focuses on environmental damage and social consequences from informal and illegal operations (e.g. Aduda & Bolf 2024; Ghosh et al. 2016). Studies examining environmental management practices in formal ASSM are limited (e.g. Gunawardhana et al. 2025), and do not clearly indicate whether key environmental standards are derived from formal instruments such as environmental impact assessments (EIA) or regulations, or from the judgment of authorities in the absence of explicit guidance. Shitima & Suykens (2023) argue that formalised ASSM requires closer examination, particularly regarding how environmental management obligations are implemented in practice and the difficulties miners face in meeting state governance standards.

This study addresses the question: what environmental management requirements apply to formally permitted ASSM operations in Indonesia, and what challenges do miners face in implementing these requirements in practice? To examine this, the study focuses on a single formally permitted operation on the Progo River in Yogyakarta Province, Indonesia. By comparing regulatory documents with field observations and interview data, the study identifies specific gaps between written standards and the operational realities of river-based sand mining. The findings demonstrate that environmental management documents for formally permitted ASSM require adaptation to local operational conditions and community knowledge; a distinction that sets ASSM apart from large-scale mining operations that typically have the technical capacity to draft and implement such documents independently.

2 Regulatory context

Indonesia applies a tiered environmental assessment system under which activities with significant impacts require a full EIA (Analisis Mengenai Dampak Lingkungan; AMDAL), while smaller operations submit either an environmental management and monitoring efforts document (UKL-UPL) or a basic commitment statement (SPPL), depending on their scale and risk level. People's Mining operations that do not use hazardous chemicals are required to submit a UKL-UPL. Permitting and approval authorities follow the same institutional hierarchy: a permit is issued by a governor or mayor, and approval rests with the relevant provincial or local authority. For most ASSM operations, permitting authority rests with provincial governments, with environmental monitoring conducted by the Provincial Environmental Agency.

Business entities may prepare a UKL-UPL independently or engage qualified third-party consultants. The document constitutes a legally binding commitment, and operators must submit progress reports to the Provincial Environmental Agency every 6 months. In Yogyakarta Province, Governor Regulation No. 7 of 2013 Concerning Businesses and/or Activities Required to Businesses and/or Activities Required to Undertake Environmental Management Efforts and Environmental Monitoring Efforts (Government of the Special Region of Yogyakarta 2013) specifies which activities require a UKL-UPL and establishes the document structure operators must follow, as summarised in Table 1.

Table 1 Structure and content of environmental management and monitoring documents. Source: authors' summary of Yogyakarta Governor Regulation No. 7 of 2013

No.	Section	General content
1	Applicant identity	Name, responsible party, address and contact details
2	Planned activity	Activity name and description, location and site map, scale and magnitude, land use compliance, activity components with potential environmental impacts
3	Environmental impact, management, and monitoring	Source, type and magnitude of impacts per operational stage, management measures, monitoring parameters, locations and frequency, responsible institutions
4	Administrative requirements	Permits, signed declaration, supporting attachments

River zones are governed by Government Regulation No. 38 of 2011 on Rivers (Government of Indonesia 2011) and Ministry of Public Works and Housing Regulation No. 28/PRT/M/2015 on the Establishment of River and Lake Setback Lines (Ministry of Public Works and Public Housing 2015). Under Article 21 of the government regulation, sand extraction may occur within the river channel and in sections where the riverbed is actively aggrading, meaning incoming sediment exceeds the river's transport capacity. Before extraction begins, operators must obtain a technical recommendation from the River Basin Management Agency and apply to the relevant mining authority for a formal permit.

Beyond Indonesia's domestic framework, other countries and international bodies have developed more detailed technical and best-practice guidance for sand mining, which provides a useful point of comparison. Malaysia's River Sand Mining Management Guideline (Department of Irrigation and Drainage 2009) and India's Sustainable Sand Mining Management Guidelines (Ministry of Environment 2016) offer the most developed examples of river-specific technical standards, setting depth limits, channel and structure setbacks, and stockpile placement requirements for both in-stream and floodplain extraction. Both frameworks address post-mining restoration specifically for floodplain mining, but neither provides an equivalent closure standard for the in-channel portion of extraction, which, in this study's case, forms part of a single operation extending from the floodplain into the active channel.

Among broader international guidance, the good practice principles for river extraction in Rogers et al. (2024) come closest to providing operational guidance, including replenishment-based extraction limits, machinery and refuelling setbacks, and pre-extraction water-quality monitoring. These principles, however, target formal infrastructure contracting rather than artisanal or small-scale operations, and do not address closure or post-extraction reclamation. The due diligence framework for sand and silicate supply chains in Organisation for Economic Co-operation and Development (OECD) (2026) and the strategic recommendations on sand governance in UNEP (2026) operate at a more general policy and supply-chain level; both name artisanal and small-scale mining (ASM) as a structurally significant but under-governed segment of the sector, without translating this into ASM-specific technical or closure guidance.

3 Methodology

3.1 Study area

The study focuses on sand extraction along the Progo River (Figure 1), a major sand source in Yogyakarta Special Province selected due to increasing extraction pressure driven by infrastructure development (Junianto 2025)

The river has a catchment area of 2,438.33 km² and a length of 143 km (Uzaer et al. 2022), with annual sand production reaching 76,680 m³ (Saputra 2017).

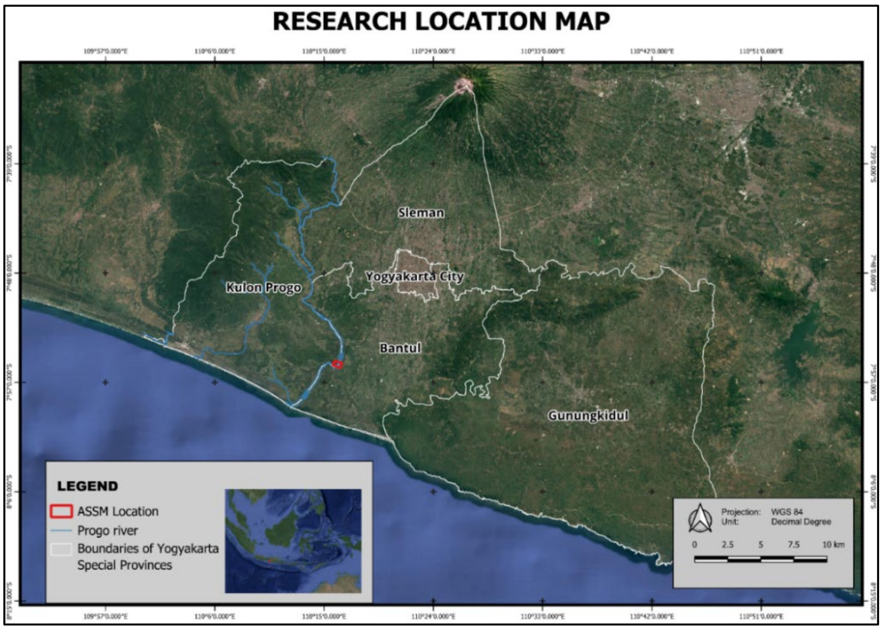

Figure 1 Research location in Yogyakarta Special Province

A single formally permitted IPR operation was selected because it underwent the same regulatory process required of all formally permitted ASSM operations in Yogyakarta Province, resulting in a UKL-UPL following the standardised structure set out in Governor's Regulation No. 7 of 2013. The permit had lapsed at the time of fieldwork, with miners in the process of applying for an extension. Site selection prioritised areas that were safely accessible and where permit status could be confirmed. The study is designed to provide contextual depth rather than broad generalisation, examining how environmental management obligations are structured and experienced in practice within a formally permitted ASSM operation.

3.2 Data collection and analysis

This study draws on 3 sources of data: the UKL-UPL, semi-structured interviews and direct field observations. Triangulation across these sources was applied to enhance validity and reliability (Smith 1995). The UKL-UPL was treated as a primary data source and analysed for its content, structure and requirements across operational stages. As an officially approved regulatory document produced by licensed consultants and signed by relevant government authorities, it meets standard criteria for qualitative document analysis (Morgan 2022). Specific document details are not cited in the reference list to protect the miner's anonymity, in accordance with the study's ethical approval conditions and the miner's request.

Two participant groups were included: 4 miners (M1–M4), who conducted mining and environmental management practices; and 3 external third-party environmental consultants (C1–C3) engaged in preparing the UKL-UPL. All were selected purposively based on direct involvement in preparing or implementing the document (Campbell et al. 2020). The participant pool was constrained by the study's single operation focus and voluntary participation, with some miners unavailable and consultants limited to those with direct experience with the ASSM document. Although a small number of interview participants were considered, these interviews provided useful insights in addition to the analyses of key documents and field observations. Government officials responsible for site supervision were not included because the relevant officers could not be identified; miners' accounts of government supervision were collected as a partial substitute.

Fieldwork was conducted between October and November 2025, with the researcher adopting a passive observation stance; documenting site conditions, post-mining land use and operational practices without direct involvement. Interview transcripts and document sections were analysed using qualitative content analysis (Elo & Kyngäs 2008) following an inductive approach across 3 stages: preparation, organising and reporting. Credibility was established through continuous dialogue among researchers, and transferability was supported by a detailed description of the research context and analytic steps.

4 Findings

4.1 The artisanal and small-scale sand mining case study profile

The planned location of the ASSM mining activities is shown by the black box in Figure 2. It identifies the work hut, the topsoil stockpile and the direction of mining. The work hut is in the small yellow box on the left, and the topsoil stockpile is in the orange box on the right. The direction of mining is indicated by the arrow inside the black box.

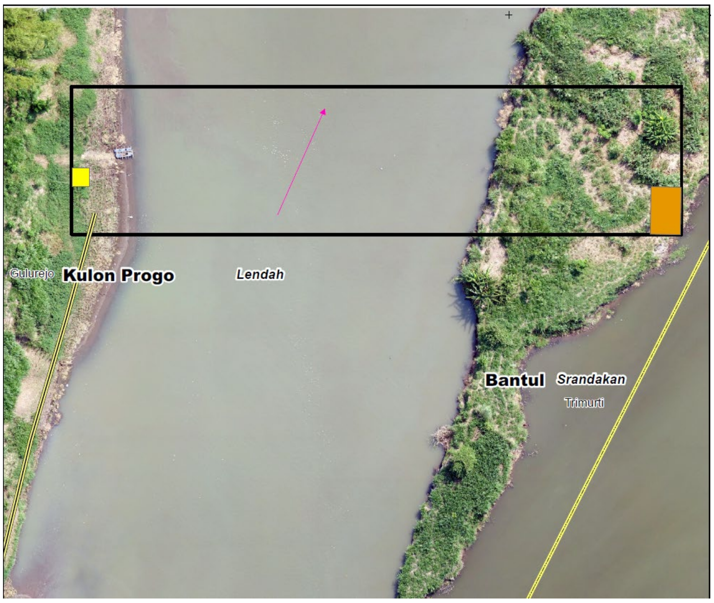

Figure 2 The planned layout for artisanal and small-scale sand mining activity. Source: Environmental management and monitoring efforts document (withheld for anonymity)

The operation covers a permitted area of 3,100 m² on the western bank of the Progo River, to a maximum depth of 1.5 m and a total extraction volume of 4,650 m³. Production is set at fewer than 10 m³ per day, using a single pump of less than 25 HP, with a projected mine life of approximately 25.79 months. The mining permit expired in May 2025. Extraction volumes were calculated from contour and cross-section maps prepared by the environmental consultant (Figure 3).

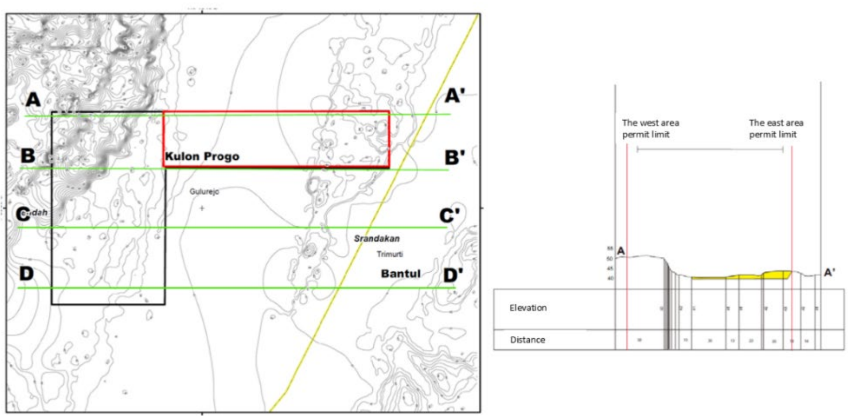

Figure 3 Contour map and cross-section map. Source: environmental management and monitoring efforts document (withheld for anonymity)

The mining group comprises 10 local members performing operational and administrative roles, drawn from a community in which approximately 55% of residents depend on sand mining as their primary source of income. Operations run from 08:00 to 17:00, 6 days a week, with the document formally acknowledging that work will pause for community social events; reflecting that operational decisions are shaped by local custom and community relationships rather than just regulatory requirements. The site was previously used for small-scale agriculture, including grasses, maize, chillies and bananas.

4.2 Pre-operation stage

Before mining could begin, the document required one pre-construction activity: community socialisation and permit processing. As shown in Table 2, both are treated as a single matrix entry with a measurable outcome defined as 100% community support. Forty-eight village residents attended the socialisation meeting, and all decisions were approved unanimously, as recorded in signed official minutes acknowledged by the village authority. Community approval is not a courtesy step but a formal compliance requirement, with a defined outcome and a monitoring method.

Table 2 Environmental management and monitoring matrix for the pre-operational stage. Source: authors, based on environmental management and monitoring efforts document (withheld for anonymity)

No.	Activity	Impact	Scale of impact	Management	Monitoring	Period
1	Socialisation and permit processing	Community perception	100% of nearby village residents support the activity	Hold community meeting, present activity and impacts, accommodate feedback, produce signed minutes, submit data and process permits per government standards	Document socialisation session, interview community members and local leaders	Minimum of once before mining commences

The socialisation process produced more than a consent record. The UKL-UPL records a formal community contribution of Rp 30,000 (approximately USD 2.00) per truckload, allocated to village development, road maintenance and a social welfare fund. This contribution was not required by law but agreed as a condition for community support. Typically, miners paid Rp 23,000 (USD 1.53) per cubic metre in extraction tax, Rp 50,000 (USD 3.33) per trip for village development and Rp 70,000 (USD 4.67) per trip into the village fund (according to interviewees M1, M2). A miner (interviewee M1) added that road concreting was funded entirely by mining revenue, not the government budget.

4.3 Construction stage

Before extraction could begin, 4 site preparation activities had to be completed: installing boundary markers, clearing land, preparing the haul road and building a work hut. Table 3 shows the management and monitoring requirements for each.

Table 3 Environmental management and monitoring matrix for the construction stage. Source: authors, based on environmental management and monitoring efforts document (withheld for anonymity)

No.	Activity	Impact	Scale of impact	Management	Monitoring	Period
1	Boundary marking	Community perception	4 GPS coordinate points defining the 3,100 m² permitted area	Install boundary markers at all 4 coordinate points per government standards, witnessed by village officials and relevant agencies, produce a formal boundary-setting document	Documentation and formal minutes witnessed by authorised agencies	Before mining commences
2	Land clearing and haul road conditioning	Social conflict	Haul road in river floodplain 604 m; village road 528 m	Clear land within permitted boundaries only, condition 604 m haul route, install traffic signs along the full route to the nearest provincial road, resolve disputes through village deliberation	Monitor and document road preparation and sign installation, produce a formal activity record	Before mining commences
3	Construction of a work hut	Community perception	Target: fewer than 5% of residents objecting	Build a work hut that does not disturb community activities, equip with a first-aid kit, personal protective equipment for all 13 workers, waste bins and group identification signage	Daily direct observation, photographic documentation	Throughout the work on the hut construction

Boundary marking was the most formally demanding requirement at this stage. GPS markers had to be installed at all 4 corners of the permitted area, witnessed by village officials and multiple government agencies, with a signed document produced as evidence (Figure 4). In practice, miners lack the technical capacity to carry out boundary plotting and rely on consultants to do it on their behalf (per interviewees C1, M1). The compliance record shows the obligation was met but it does not indicate that operators understood or could independently verify what was done.

Figure 4 Boundary marker installation at a permitted sand mining site on the Progo River, with a compass survey in progress. Courtesy of PT Arsyanendra Panca Energi

Both the no-swimming warning sign and boundary markers had disappeared, lost to flooding (per interviewees M1, M2), and the group now relies on tree locations to remember the edge of the permitted area (per interviewee M2). A formal GPS-defined boundary, witnessed by multiple agencies, had been replaced in practice by informal spatial memory. Traffic signs installed along the 604-metre haul route had similarly been lost to flooding (per interviewees M1, M2). The document required proof of installation before mining began but no ongoing checks, leaving no mechanism to detect or respond to their loss.

Work hut equipment, including safety gear, a first-aid kit, waste bins and a life preserver on a 25-metre rope, (Figure 5) was absent during the field visit. The life preserver and rope had been taken home to prevent theft (per interviewees M1, M2).

Figure 5 Miner's working hut

4.4 Operation stage

The operational stage is the most detailed section of the document. Table 4 sets out management and monitoring requirements across 8 areas: community relations, local employment, river function, worker safety, dust and air quality, solid waste, road damage and traffic.

Table 4 Environmental management and monitoring matrix for the operation stage. Source: authors, based on environmental management and monitoring efforts document (withheld for anonymity)

No.	Activity	Impact	Scale of impact	Management	Monitoring	Period
1	Mining and transport	Negative community perception and social conflict	Target: fewer than 5% of nearby village residents	Carry out pre-agreed community commitments, maintain a complaints channel, resolve disputes through village deliberation	Direct observation, interviews with community leaders and residents	During operations
2	Sand extraction	River function damage	3,100 m² permitted area, max depth 1.5 m	Limit excavation to 1.5 m, use a pump ≤ 25 HP; keep stockpiles ≥ 100 m from the riverbank, cap production < 10 m³/day, coordinate with mine inspectors	Direct observation, mine progress mapping and documentation	Before and throughout operations
4	Sand extraction	Worker safety and health	13 workers	Provide PPE for all workers, maintain a first-aid kit; post safety in the working hut and evacuation procedures, conduct safety briefings	Monthly observation: check PPE and worker safety awareness	Monthly throughout operations
5	Sand transport	Dust, air quality, road damage and traffic	25 houses and 528-m village road	Water roads in dry season, cover loads, slow near homes, partially drain sand before loading, limit loads to 4.7 m³, repair road damage, station traffic controllers at junctions, use designated haul route, avoid peak hours	Resident interviews, observations, road monitoring and biannual lab air tests	During transport operations
6	Mining and transport	Solid domestic waste	5.2 kg/day of domestic waste from 13 workers	Provide separated waste bins, apply the reduce-reuse-recycle principle, prohibit open burning	Direct observation, waste volume recording	During operations

River protection is enforced through operating rules: extraction depth is limited to 1.5 metres from the riverbed, stockpiles must be kept at least 100 metres from the riverbank and daily production must stay below 10 m³. One miner reported that extraction pipes extend up to 15 metres below the water surface and argued that a 2–3 metre regulatory limit makes no sense given that floodwater alone can raise the river surface by up to 6 metres (interviewee M3). A consultant noted that Progo riverbed deposits are dynamic, and usable sand is not always found within the permitted excavation depth, creating a consistent gap between what is approved on paper and what happens in the field (interviewee C3). No water-quality or sediment monitoring is required during operations, and one miner argued that good-quality sand acts as a natural filter (interviewee M4); this perspective overlooks the significant sediment disturbance around the extraction site. Before extraction began, a contractor's excavator stripped topsoil from the permitted area (interviewee M3), corroborated by the official mine layout map, yet the UKL-UPL matrix contains no management, monitoring or rehabilitation requirements for topsoil handling. Stripped topsoil is stored separately and planted with fodder grass during operations, allowing miners and villagers to harvest grass for cattle (interviewee M2). Because this is an informal, community-driven practice rather than a regulated one, topsoil placement often appears irregular, and replanting remains unsystematic (Figure 6).

Figure 6 Topsoil bank

In practice the operation uses 2 24 HP pumps totalling 48 HP, with a third added when ground conditions are difficult, bringing total capacity to 72 HP (interviewee M1); well above the permitted 25 HP specification. Figure 7 shows the raft equipped with 2 pumps. The government response was to cap horsepower per pump rather than address the operational reality (interviewee C2). Consultants stated that the document represents an ideal version of the operation, and that actual practice reverts to miners' own judgment once operations begin (interviewees C1, C3).

Figure 7 Suction boats that are moored because operations have stopped, with the oil bucket

The document states that all pump maintenance is carried out at group members' homes, generating no hazardous waste on paper. In reality, a blue bucket on the raft collects onsite oil (Figure 7), minor leaks are tolerated until the boat reaches shore and used oil is taken home as cooking fuel for cattle feed (interviewees M2, M3). No formal disposal or monitoring requirements are prescribed. Worker safety is the only category with a defined monthly monitoring schedule, yet compliance is low: no safety training has ever been provided (interviewee M1), daily preparation consists of equipment checks rather than safety briefings (interviewee M2), and helmets and boots are unworkable on a bamboo raft mid-river (interviewees M1, M4). Dust, road, traffic and solid waste requirements are set out in Table 5. However, miners provided no air-quality monitoring records and operations were halted during the visit, limiting direct observation of the remaining practices.

4.5 Post-operation stage

The post-operation stage covers 3 formal closure activities: land rehabilitation, work hut dismantling and village road repair, and vetiver grass (*Chrysopogon zizanioides*) planting along the river embankment, as summarised in Table 5.

Table 5 Environmental management and monitoring matrix for the post-operation stage. Source: authors, based on the environmental management and monitoring efforts document (withheld for anonymity)

No.	Activity	Impact	Scale of impact	Management	Monitoring	Period
1	Land rehabilitation	Return of river function and land use	3,100 m² excavated area, max depth 1.5 m	Create gently sloped surfaces to eliminate vertical walls, arrange land in consultation with community members	Documentation of activities and final site condition	During and after rehabilitation
2	Work hut dismantling and village road repair	Community perception	528 m village road used as a haul route	Dismantle work hut without leaving waste, repair village road to pre-mining condition or better, accommodate community input	Documentation of repair activities, resident interviews on road condition	End of mining period
3	Vetiver grass planting along the river embankment	Community perception	About 26 m of embankment at the haul-road crossing: 6 m road plus 10 m each side	Plant vetiver at the haul road embankment crossing and coordinate with the river basin authority	Observe plant survival, document planting in formal minutes	End of mining period, one observation check one month after planting

Compared to 8 monitored impact categories during operations, the post-operation stage has only 3 closure activities with vague timing and no completion standards. Land rehabilitation requires grading the excavation edges to eliminate vertical drops and consulting with community members on post-mining land arrangements. No soil quality target, ecological recovery measure or post-rehabilitation monitoring schedule is defined. Where fill material is available, stripped topsoil is returned and the land replanted with fodder grass; a practice miners described as a livelihood decision rather than a soil protection measure (interviewees M2, M3). Where fill is unavailable, the ex-mining area becomes a groundwater-fed pond stocked with fish and periodically harvested by the landowner (interviewee M2). Cassava, bananas and corn were observed growing around the pond (Figure 8), while flood events gradually deposit sediment into the hollow, slowly restoring dry land (interviewee M3).

Figure 8 Former sand mining area in the Progo River floodplain, showing a fishpond formed after mining ceased

At the time of the visit, the work hut remained standing and in use as a rest shelter; kept in anticipation of a permit extension (interviewee M2). The haul road had not been formally restored, though miners reported contributing to the village road maintenance fund throughout operations, and the road remained in active community use for farming (interviewee M1).

No participant mentioned vetiver grass planting during interviews, and no evidence of planting was observed during the field visit. Natural grass had colonised the riverbank (Figure 9). A consultant noted that community members routinely plant chilli, cassava and corn in the floodplain despite regulations permitting only grass in riverbank zones (interviewee C1).

Figure 9 Natural grass colonisation on the Progo Riverbank in the ex-mining area

Three structural deficiencies apply across all post-operational activities: there is no financial assurance mechanism, there are no completion standards defining what a finished outcome looks like (or who decides when obligations have been met), and there is no dedicated closure oversight beyond the mine inspector and regional environmental agency.

5 Discussion

5.1 The environmental management and monitoring efforts document as a permit requirement rather than a management tool

The most important finding is not that the UKL-UPL contains the wrong requirements, but that the document mainly serves to secure permit approval and has little practical influence on day-to-day operations. Consultants acknowledged that what they write is an ideal description designed to meet regulatory requirements rather than a realistic account of what will happen on the ground, and that operational decisions revert to miners' own judgment once the permit is issued. This is reflected in what miners knew and did not know about the document: they were unfamiliar with its contents, could not independently verify their own operational boundaries and did not provide required air-quality monitoring reports. This situation is consistent with Spiegel's (2012) finding, based on participant accounts in Indonesian artisanal gold mining, that environmental documents are produced mainly to satisfy legal requirements, leaving miners without the knowledge or tools to act on them. Receiving a permit and having the practical capacity to meet its requirements are 2 different things, and the current framework does not yet bridge that gap.

Government supervision reinforced this pattern. The most frequent visits focused on production volumes for tax collection. Environmental compliance inspections occurred only occasionally and were conducted from the riverbank without direct engagement with operational activities (interviewees M1, M3, M4). This points to a structural gap: inspections are focused on revenue collection rather than verifying whether practices align with UKL-UPL commitments.

This gap between inspection practice and document requirements is likely common elsewhere in Indonesian ASSM, but it only became visible here because the UKL-UPL was examined directly rather than described second-hand. Existing comparative studies of ASSM environmental governance, including cases from Rwanda (Bendixen et al. 2024), Tanzania (Shitima & Suykens 2023), Sri Lanka (Gunawardhana et al. 2025) and Bangladesh (Suykens et al. 2025), describe regulatory requirements either from policy texts or from participants' accounts of what officials require, but none independently obtain and analyse an individual operation's environmental compliance document as a primary source checked against observed practice. This study takes that approach, treating the UKL-UPL itself as the primary document for analysis.

5.2 Requirements that do not fully fit the working environment

Several requirements were written for mining in general rather than for the specific conditions of river-based sand extraction. The 1.5-metre extraction depth limit illustrates this clearly. The limit carries a legitimate environmental purpose, but the document does not explain that it refers to the maximum thickness of sand extracted from the riverbed, not the distance from the water surface. One miner argued that the limit is not based on the field reality, given that floodwater alone can raise the river surface by up to 6 metres (interviewee M3); revealing a fundamental misunderstanding that the document does not address. The limit is further complicated by sediment dynamics, as flood events alter the riverbed surface from which the 1.5-metre excavation depth is measured, and usable sand is not always found within that permitted depth. Verifying compliance is also impractical, as government inspectors conducted inspections from the riverbank without boarding the raft, making extraction depth verification impossible. A comparable challenge has been documented in Tanzania, where regulatory depth limits existed but were never verified in practice (Shitima & Suykens 2022).

Equipment, safety and boundary requirements reflect the same problem. The document specifies one 25 HP pump but 2 are required to operate effectively, with a third added in difficult conditions. Safety equipment prescribed for a generalised mining context is unworkable on a bamboo raft mid-river, and no safety training has ever been provided. Boundary markers were formally witnessed by multiple agencies but destroyed by flooding, with no requirement to reinstate them; leaving miners to rely on informal spatial memory. Without an explanation of purpose or practical guidance suited to the actual working environment, these requirements produce predictable gaps between what is prescribed and what happens on the ground.

These gaps reflect overlapping causes rather than a single explanation. Some stem from legislative design: the depth limit and pump specification were written without reference to river dynamics or actual operational needs; a pattern consistent with a regulatory history built primarily around surface and underground extraction (Octaviano et al. forthcoming). Others stem from enforcement capacity where existing inspections practices are insufficient to verify compliance with river specific requirements.

Another pattern reflects economic pressure overriding regulatory limits: M1 described buyers requiring loads of 10 to 11 m^3 before they would purchase, rejecting volumes below that threshold, and stated that transport authorities do not enforce the daily production limit. This pressure plausibly reflects truck logistics: filling a single truck to capacity is cheaper for a buyer than renting a second vehicle to carry the remainder, though this study did not directly confirm the buyers' reasoning. Whatever the underlying motive, the direction of pressure runs from buyer to miner, not the other way around: M1 frames continued production above the regulatory limit as a response to buyer demand rather than as an independent choice.

5.3 Post-mining governance: current gaps and emerging responses

The post-mining stage is where the framework is weakest. A site visit 5 months after the permit expired found that none of the formal closure requirements were fulfilled: the work hut remained standing, the haul road was unrestored and the vetiver planting had not been carried out. The framework has no completion standards, no defined timelines and no financial assurance mechanism, meaning closure depends entirely on what operators choose and can afford after mining income has ceased.

Miners did carry out substantive informal practices, including topsoil storage and return, and the conversion of ex-mining areas into fishponds, but these are unguided, and the outcomes reflect it: topsoil replacement was irregular, replanting was unsystematic and water-filled pits carry residual mosquito breeding risks that active landowner management reduces but does not eliminate. Self-initiated efforts are valuable but insufficient: without formal guidance, defined outcomes and oversight, rehabilitation quality varies between sites and depends on factors that regulators cannot control or verify.

The absence of a financial mechanism to support post-mining rehabilitation meant that closure depended entirely on what individual operators chose and could afford after mining income had ceased. Financial constraints are one reason informal rehabilitation efforts fall short, but not the only one. This study also identified limited technical knowledge among operators, inadequate equipment, the absence of safety and environmental training, and an inspection system unable to verify compliance in a river environment. Addressing these barriers requires a comprehensive and proactive governance approach that goes beyond financial provision: one that pairs funding with accessible technical guidance, trains miners in site-specific environmental management, equips inspectors to conduct meaningful onsite verification, and establishes clear rehabilitation standards with defined timelines and completion criteria.

The recently published Ministry of Energy and Mineral Resources Decree No. 174.K/MB.01/MEM.B/2024 on IPR Guidelines (Ministry of Energy and Mineral Resources 2024) addresses some of these gaps; establishing a reclamation funding mechanism through the People's Mining levy (Iuran Pertambangan Rakyat; IPERA) and a standardised reclamation plan document with defined chapters and completion criteria. The decree applies to IPR holders across all commodities rather than offering only general, non-binding recommendations, but it does not address sand- or river-based extraction specifically: its technical mining standards are organised around 2 named methods, open pit and underground extraction; an operation spanning floodplain and in-channel zones, such as the one examined in this study, receives no equivalent section.

This gap extends beyond Indonesia's domestic framework. None of the international instruments reviewed in the background, including Malaysia and India's technical guidelines or broader frameworks such as OECD (2026) and UNEP (2026), provide closure or extraction-method guidance suited to an operation spanning floodplain and in-channel zones at artisanal and small-scales. For the in-channel portion of extraction, none specifies a closure or restoration requirement for the riverbed or channel itself. For the floodplain portion, however, Malaysia's and India's technical guidelines do offer a referable starting point; requiring restoration of floodplain pits to wetland habitat or agricultural use, with side-slope and topsoil placement requirements that could inform practice even though they were not developed for artisanal or small-scale operations. No equivalent reference point exists for closing the in-channel component of an operation such as the one examined in this study.

6 Conclusion

This study offers the first document-grounded analysis of how a formally permitted artisanal and small-scale sand mining (ASSM) operation in Indonesia meets its environmental obligations in practice. The central finding is not that the environmental management and monitoring efforts document contains the wrong requirements, but that the environmental document functions as a permit instrument rather than a management tool, with requirements that do not fully account for the physical realities of river-based extraction, and a post-mining stage that lacks the standards, timelines and oversight needed to ensure rehabilitation actually occurs. These problems stem from a framework that prioritises permit approval over operational guidance, applies generic standards without adaptation to river environments, and concentrates regulatory attention at the start of operations while leaving the post-mining stage underspecified and unenforced. As this study examined a single site this cannot be confirmed beyond the case studied here, but other formally permitted ASSM operations under the same framework may face similar challenges.

Future research should investigate how technical standards for river mining are determined and whether site-specific conditions inform that process, given that several requirements in this study were found to be poorly suited to a dynamic floodplain environment. Research should also examine how onsite inspections of

ASSM operations are conducted and what inspectors can realistically verify, since this study found that riverbank-based inspections could not confirm depth compliance. Understanding how local communities perceive post-mining rehabilitation and participate in land use decisions would further strengthen the evidence base for governance reform.

The broader point is simple. An environmental document should not function only as a permit requirement. It should be a practical guide that helps miners understand their obligations and gives the government a meaningful basis for monitoring compliance. Building that requires collaboration between government, consultants, academics and miners in language that all parties can understand and act on.

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Use of artificial intelligence disclosure statement

In the preparation of this work, the authors used Microsoft Copilot to assist with clarity and readability. The authors have reviewed the content and edited it where required and take full responsibility for said content.

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